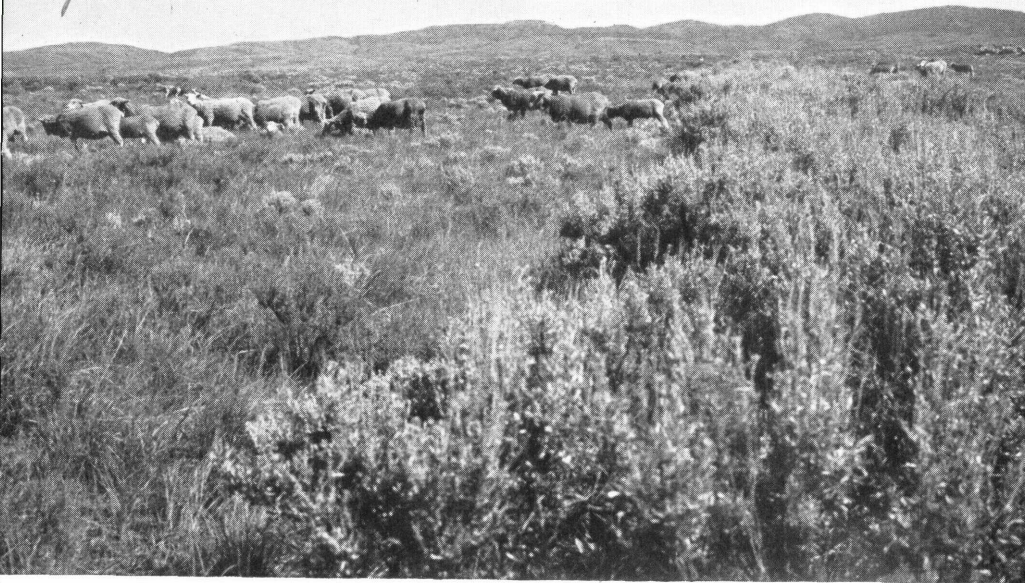


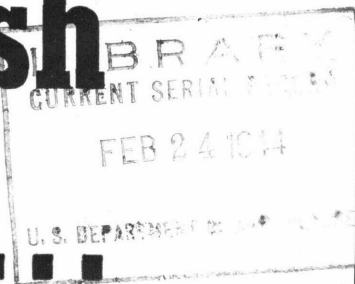
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Sagebrush Burning . . .



GOOD AND BAD

FARMER'S
BULLETIN
NO. 1948



U. S. DEPARTMENT
OF AGRICULTURE

THE USE OF FIRE TO REMOVE BRUSH that interferes with the production of forage and the handling of livestock on western range lands has long been a controversial subject. It has been condemned because of the harmful, often disastrous, consequences of widespread haphazard or accidental burning. Promiscuous burning of sagebrush has played havoc on literally millions of acres of range land, removing the sagebrush but leaving the soil exposed to erosion by wind and water, because the burning was done in places or in a manner which discouraged the immediate reestablishment of grass and other forage cover. So much damage has been done by ill-advised burning that most of the Western States and the Federal Government have imposed severe restrictions on the unauthorized use of fire.

The results of investigations described in this publication have shown, however, that, when properly used, burning to remove dense stands of big and threetip sagebrush can under certain conditions be a useful tool in improving the production of forage on range lands. Carefully planned burning, when properly carried out, is an effective means of increasing forage production, a matter of immediate importance at this time in the food production program. Although the guides herein outlined apply directly to the dense sagebrush-grass ranges of southeastern Idaho where the investigations were conducted, it is believed that they will be applicable, possibly with some modifications, to local conditions on other western ranges where dense stands of big and threetip sagebrush constitute a grazing problem, provided the burning does not endanger other land values.

Burning is like a fine tool or intricate machine; if it is to be used with any success it must be used skillfully, and that use must follow an intelligent plan. The simple, practical rules and guides set forth here on where, when, and how to burn, and the grazing management to be used after burning, if followed carefully, will afford a reasonable chance for improvement of the range and help to avoid the damage that so frequently follows haphazard or promiscuous burning.

Where planned burning of sagebrush is to be undertaken on any area, it should first be tried out on a small scale to test its effectiveness and to determine the safeguards that should be followed to meet the hazards for a given set of conditions. It goes without saying that the use of fire to remove sagebrush for range improvement should be attempted only with the approval of local fire-control authorities.

LYLE F. WATTS,
Chief, Forest Service.

SAGEBRUSH BURNING—GOOD AND BAD

By JOSEPH F. PECHANEC, *associate forest ecologist*, AND GEORGE STEWART, *senior forest ecologist, Intermountain Forest and Range Experiment Station,¹ Forest Service*

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THE SAGEBRUSH PROBLEM

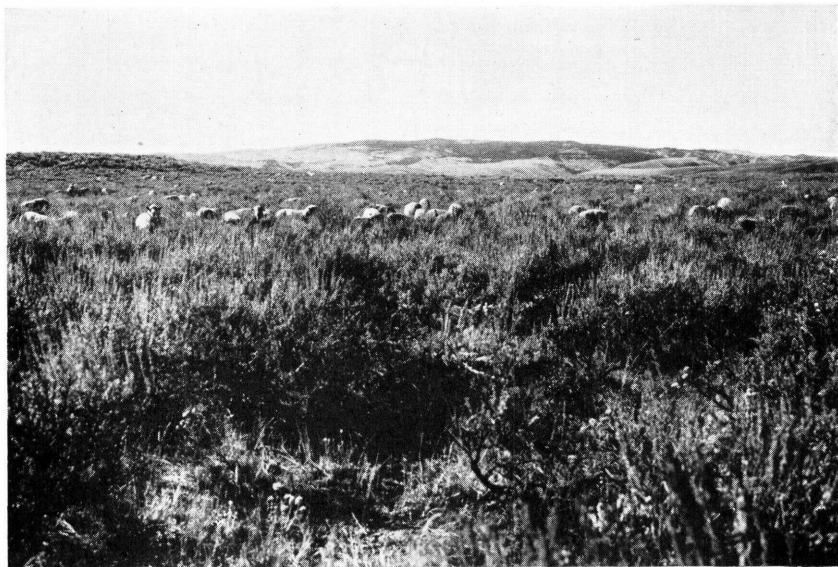
ON RANGE where dense stands of big and threetip sagebrush materially reduce the value of the lands for grazing, stockmen often resort to burning to remove the sagebrush. Their justification for so doing lies in the difficulties and losses for which the dense sagebrush is responsible. Livestock cannot graze satisfactorily into such dense stands (fig. 1). Even when they force their way into the shrubby growth, half the palatable grasses and weeds beneath the sagebrush are likely to be unavailable to them. Ewes and lambs become separated and frequently are not reunited until nightfall. Lamb losses are increased through straying, or the lambs are caught by predators hidden in the dense growth. The stiff brush pulls wool from the fleeces. Grazing capacity is markedly reduced. Cattle graze sagebrush hardly at all and sheep graze it only lightly. Furthermore, the sagebrush deprives the more palatable perennial grasses and weeds of much of the available soil moisture.

Where usability of the range can be increased and the quantity and quality of forage improved, the stockman's need to remove the dense sagebrush stands is obvious. His use of burning, as a means to this end, has often proved effective. The difficulty is, however, that fires started to reduce sagebrush are rarely planned from start to finish and are seldom properly controlled. Consequently, they may cause serious losses not only to the livestock industry but to other private and public interests. Every year such fires started on sagebrush range consume forage and expose the soil to erosion on hundreds of thousands of acres, and too often farm crops, buildings, and even farm and range animals are destroyed.

¹ The authors gratefully acknowledge their indebtedness to G. D. Pickford, now Senior Forest Ecologist, Pacific Northwest Forest and Range Experiment Station, Portland, Oreg., under whose direct supervision work on this study was begun in 1932 and carried to 1936. They wish to express appreciation also to the Fremont County Woolgrowers' Association and the State of Idaho for their cooperation in conducting the work of the Fremont County burning project; to the Bureau of Animal Industry for their cooperation on the sagebrush-burning projects at the U. S. Sheep Experiment Station, Dubois, Idaho; and to the committee composed of Walt L. Dutton, Chief of Division of Range Management, P. A. Thompson, Chief of Division of Fire Control, W. R. Chapline, Chief of Division of Range Research, of the Washington office of the Forest Service; C. N. Woods, Regional Forester, Ogden, Utah; and Reed W. Bailey, Director, Intermountain Forest and Range Experiment Station, for their technical aid in the development of the study and of this bulletin.

Even when these sagebrush fires are accidental, lack of appreciation of the damage they can do has often been responsible for allowing them to attain such proportions that their prompt control is extremely difficult. Ravages of such fires, as well as of intentional fires poorly controlled, cost the public and the private interests directly concerned hundreds of thousands of dollars annually.

Property damage caused by unwise and uncontrolled fires and the annual cost of control and suppression of sagebrush fires have prompted State and Federal governments to attempt to curb the use of fire. Laws have been enacted making it a criminal offense or misdemeanor to set fires on or near



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FIGURE 1.—Dense stands of sagebrush such as these constitute a major range problem for cattlemen as well as for sheepmen. Livestock cannot graze satisfactorily into these stands. Here a band of ewes and lambs can hardly be seen in the 2-foot to 3-foot sagebrush. Burning off this sagebrush growth, if properly planned and controlled, will improve the range; but haphazard burning may prove very costly and result in serious forage losses.

lands under Federal or State jurisdiction without a permit, or to allow a fire which has been set to escape to these lands.

Often the ineffective control of the actual fire is not the worst feature of the burn. Lack of protection for the area after the burn may cause greater losses. Grazing and trailing livestock across the burned range in the succeeding fall and winter, or even the following spring, when forage supply is still scant or absent, is extremely likely to speed up soil erosion and damage the range forage irreparably.

It is clear that stockmen have a hard problem in these dense sagebrush stands, but it is equally clear that the problem cannot be solved by haphazard burning. Recognizing the need for a real solution, the Intermountain Forest and Range Experiment Station of the Forest Service, in cooperation with the Fremont County Woolgrowers' Association and the State of Idaho, undertook in 1932 a study of the effects of burning and grazing management in dense sagebrush stands on spring-fall ranges of the upper Snake

River plains of southeastern Idaho. The burning experiments were repeated at two other locations on somewhat similar spring-fall range at the United States Sheep Experiment Station range in nearby Clark County, Idaho, by the Forest Service, in cooperation with the Bureau of Animal Industry. In all, approximately 6,000 acres of dense sagebrush range was experimentally burned under management. Results from other burns in the vicinity of these experimental studies were also closely observed during the 10-year period 1932 to 1942.

While these research findings apply directly to the upper Snake River plains, they may prove helpful in reducing dense stands of big and threetip sagebrush in other semiarid range areas of the West. Big sagebrush occurs from western Nebraska to Montana, British Columbia, eastern California, and northern New Mexico, and covers a wide elevational range. Threetip sagebrush has a more restricted distribution. The findings, of course, cannot be applied to those sagebrush or other brushy species that are not readily killed by fire, nor should burning be attempted where it would endanger timber reproduction or watershed, recreational, or other land values.

The chief value of these studies is the contrast they offer between the results of the common type of burn—which can reasonably be termed “haphazard,” since it is characteristically done with little provision for adequate control and no plan for livestock management after the burn—and the results of planned burning, which not only provides for a safe, effective burn with the least possible damage to existing forage, but also includes equally effective provisions for protection of the range after the burn, to permit the desirable forage plants to become reestablished before grazing is resumed.

Several methods other than burning are in use throughout the sagebrush type for reducing or eradicating stands of dense sagebrush, including railing (dragging with railroad rails), breaking it down with bulldozers, plowing with a heavy disk plow, mowing, and flooding. Each of these gives good results under certain conditions, and when they can be utilized to advantage they should be used in preference to burning.

GOOD RESULTS FOLLOW PLANNED BURNING

The sagebrush-burning experiments in Clark and Fremont Counties of southeastern Idaho show that increased usability and greater grazing capacity of the range without damage to adjacent property are dependable results of planned burning (fig. 2). This is because planned burning is a well-thought-out program of range improvement by the use of fire. It is carried out only after careful consideration of whether the area concerned may properly be burned at all and, if so, what are the proper time and manner of burning; it includes adequate control of the fire used in burning; and it invariably provides for careful grazing management after burning. Three different experimental burns were made, all on level or rolling range, one in 1933, one in 1936, and one in 1939. Each area had a good understory of perennial grasses and weeds before burning. Each fire was set in the late summer and was held within bounds by fire lines and trained crews. Grazing or trailing by livestock was excluded from the burns for a full year; thereafter, grazing was moderate in degree and otherwise carefully regulated.

The result was to increase grazing capacity an average of 69 percent on these experimental burns (fig. 3). Perennial grasses and weeds increased



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FIGURE 2.—Grazing capacity and usability of this range have been greatly increased by planned burning, including proper livestock management. Six years after the burn there is an abundance of perennial grasses and weeds, with sagebrush practically eliminated. This area is 1 mile from that shown in figure 1.

60 percent in abundance, partially replacing the sagebrush (fig. 4). This increase in the more palatable species, made up of a doubling in perennial grass and a 25-percent increase in perennial weeds, plus a change from 64 to 93 percent in availability, brought about the increase in grazing capacity. Much of this increase had come about by the second season. On what may have been a more satisfactory site in the Laramie River valley of northwestern Colorado, the Colorado Agricultural Experiment Station²

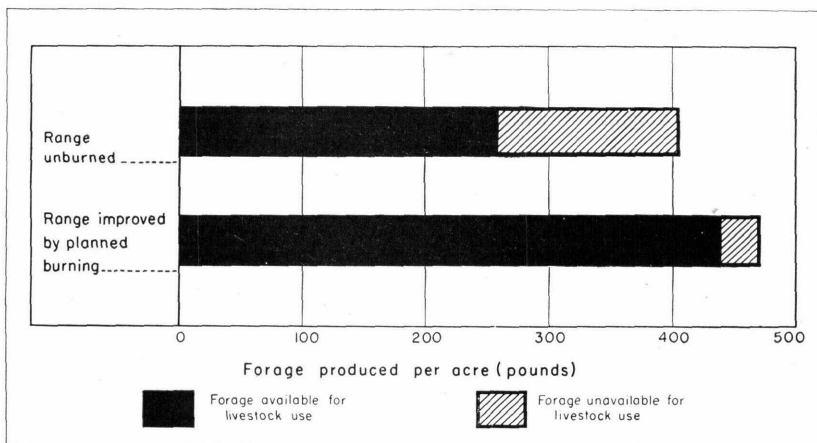


FIGURE 3.—Planned burning materially increases grazing capacity, the increase representing both greater forage production and greater availability of the forage produced.

² HANSON, H. C. IMPROVEMENT OF SAGEBRUSH RANGE IN COLORADO. Colo. Agr. Expt. Sta. Bul. 356, 12 pp., illus. 1929.

MORRIS, M. S. INCREASING FORAGE ON SAGEBRUSH LAND. Colo. Agr. Col. Ext. Bul. 308-A, 7 pp., illus. 1931.

obtained a 300-percent increase in grazing capacity. Not only was dense sagebrush completely removed but also adequate care in grazing management after burning encouraged so striking an increase of the desirable perennial grasses and weeds that reseeding after burning was not necessary.

These very good results were obtained because in planned burning it is recognized that increased grazing capacity does not come about immediately. Usually, when the dense sagebrush (fig. 5, *A*) has been completely removed, the burned area remains free of any plant cover until the following spring, except for charred grass tufts and stubs of burned shrubs. Early in the spring perennial grasses, weeds, and shrubs begin growth from the tufts, root crowns, and rootstocks of the plants that have survived, but very few perennial seedlings come in.

This plant growth is stunted and scattered (fig. 5, *B*), unable to withstand grazing. Even so it appears more vigorous than it really is. Ap-

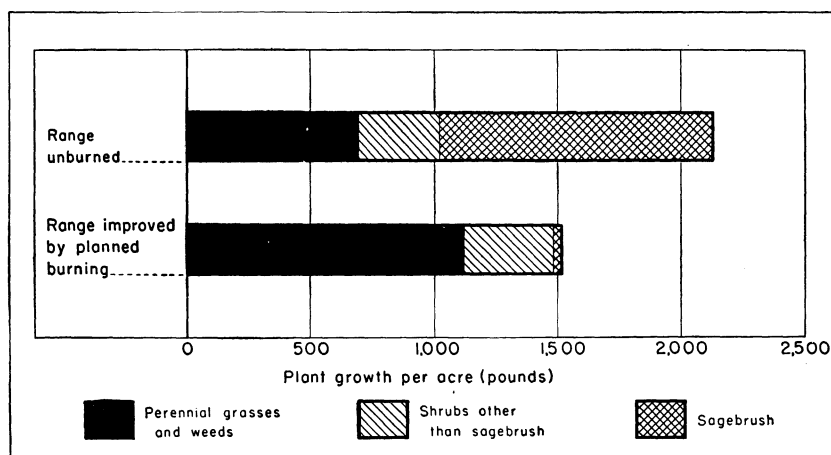


FIGURE 4.—Under planned burning, sagebrush is almost completely removed, permitting an immediate increase in perennial grasses and weeds of 60 percent.

pearances are unreliable, since in the burned stand the growth is no longer concealed by the sagebrush and the dried residue of previous years' growth, and so seems to have increased. It is only upon careful comparison with growth on unburned areas that the true reduction in vigor is evident. Little if any seed is produced by the perennials the first year after burning. Much of the ground space may be occupied by annual weeds.

During the second spring after burning, perennial grasses and weeds stool out and take up much of the moisture formerly used by sagebrush. The fact that all species produce an abundance of flower stalks is likely to give an erroneous impression that the range is better this second year than in any following year. It is only in the third or even the fourth year after burning, however, that the perennial grasses and weeds increase sufficiently to make full use of all of the moisture in the soil (fig. 6). Litter has accumulated on the ground and protection to the soil is as great as on unburned range or greater.

Usability of the range on the southeastern Idaho burns was greatly improved by the almost complete removal of the sagebrush. Big sagebrush was completely killed and only 6 percent of the threetip sagebrush sprouted. Four, three, and two plants per 100 square feet had come in by 1942 respec-



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FIGURE 5.—The immediate result of a good burn in a dense stand of big sagebrush, as shown by two views of the same plot. *A*, The perennial grass and weed understory formed 30 percent of the total cover, but little of it is visible and only 40 percent of it was available for livestock use. *B*, The need for protecting the range the first spring after burning is very apparent. Perennial grasses and weeds are scattered and low in vigor; much of the soil is so unprotected that any trampling will cause it to loosen and blow away. The profit to the operator in protecting such an area from grazing is evident in figure 6.

tively on the 1933, 1936, and 1939 burns, whereas dense stands of big sagebrush commonly consist of 30 to 40 mature plants per 100 square feet. Most of the young sagebrush plants came in during the first year or two after burning, before the grass stand thickened; since then the strong competition by grasses and weeds has greatly weakened their vigor. Thus it appears

likely that improvement in usability of the burned areas can be indefinitely prolonged by good grazing management.

Handling of range livestock has been greatly simplified following the burns. Sheep and cattle move about and graze without any difficulty. Ewes and lambs, on these lambing or early spring ranges, can remain close together at all times, so that ewes produce a continued flow of milk and the young lambs make better growth. Loss of lambs by straying from the flock or from predators is sharply cut. Wool losses due to brushing have been reduced if not eliminated.

Soil losses from planned burning were light, and soil movement, accelerated to some extent immediately after burning, was arrested almost completely by the end of the first spring season.

Range with but little understory of perennial grasses and weeds should not be burned unless it is to be reseeded the first fall following the burn.



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FIGURE 6.—By the third or fourth year after burning, provided that grazing has been properly controlled, the perennial grass and weed stand has thickened and is making use of all the soil moisture formerly used by sagebrush. Litter accumulates on the soil surface and protection to the soil is greater than on unburned areas. This picture of the site shown in figure 5 was taken 6 years after the burn. The shrub showing conspicuously in the center and background is spineless gray horsebrush.

Failure to follow this procedure has been responsible for the lack of protective plant cover on many burned-over areas. When reseedling is included as a part of the burning plan, marked increases in grazing capacity and usability of the range are obtained. Planned burning must include reseedling the first fall following the burn. In connection with Intermountain Forest and Range Experiment Station studies in artificial revegetation, a tract burned in southeastern Idaho was reseeded the same year to crested wheatgrass. Three years after reseedling, this productive tract had a grazing capacity of $2\frac{1}{2}$ animal-unit-months per acre, or many times as much as before the burn (fig. 7). At Clover Creek, in northern Nevada, range similarly burned and reseeded to crested wheatgrass had within 3 years a

grazing capacity of 1 to 1½ animal-unit-months per acre, more than 12 times as much as adjacent land unburned and reseeded. Near Mountain Home, in southwestern Idaho, the Soil Conservation Service found that reseeding after dense sagebrush was burned increased grazing capacity from 20 acres per animal-unit-month to 4 acres. In all these cases the stands of perennial grasses established by reseeding were very effective in preventing further soil erosion or the return of sagebrush.

But even planned burning has some undesirable effects. Such valuable plants as Idaho fescue, bitterbrush, and the partially shrubby weeds are badly damaged by fire and require a prolonged period of careful management for recovery. One-half to two-thirds of the Idaho fescue and three-



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FIGURE 7.—Reseeding after burning is necessary where there is an insufficient understorey of perennial grasses before the burn. This area was burned 3 years before the picture was taken and reseeded that same fall to crested wheatgrass. It now has a grazing capacity of 2½ animal-unit-months per acre, or many times the grazing capacity of the unburned area. What this range was like before burning is indicated in figure 9. Figure 10 shows what happens when reseeding is not employed on range where before the burn perennial grasses and weeds were insufficient or absent.

quarters of the bitterbrush were killed by burning on the three experimental burns. It took 9 years for bitterbrush to regain its losses on the area burned in 1933, and Idaho fescue has not yet returned to its former abundance. This is not especially harmful on the areas studied, where Idaho fescue and bitterbrush were minor species; but were these species dominant, or others not resistant to fire, their loss would be serious.

Another unfavorable result is the drying-up of the forage on burned ranges a week to 10 days earlier in the spring than on unburned ranges. If sheep, especially ewes with young lambs, are on burned ranges after this time, they will travel excessively in search of more succulent forage. Further, the value of fall forage for use during cold periods is often reduced through burning, especially if sagebrush and bitterbrush were the only two shrubs on the area before burning. Ordinarily shrubs form a substantial portion of the fall sheep ration on sagebrush ranges, especially during cold periods. When sagebrush is removed and bitterbrush badly damaged by the fire

and no other browse is available, the sheep are dissatisfied and will travel widely and constantly.

From a practical standpoint, sagebrush range should never be burned over where these undesirable features, especially damage to dominant species, are not more than outweighed by the prospective increase in forage supply and decrease in difficulty of handling livestock. At least, under such conditions, planned burning should not cover the entire range in one operation, but should be applied on a part at a time. In this way the undesirable results of the burn, which would be serious if the entire range were the burning unit, will have a negligible effect in any one season.

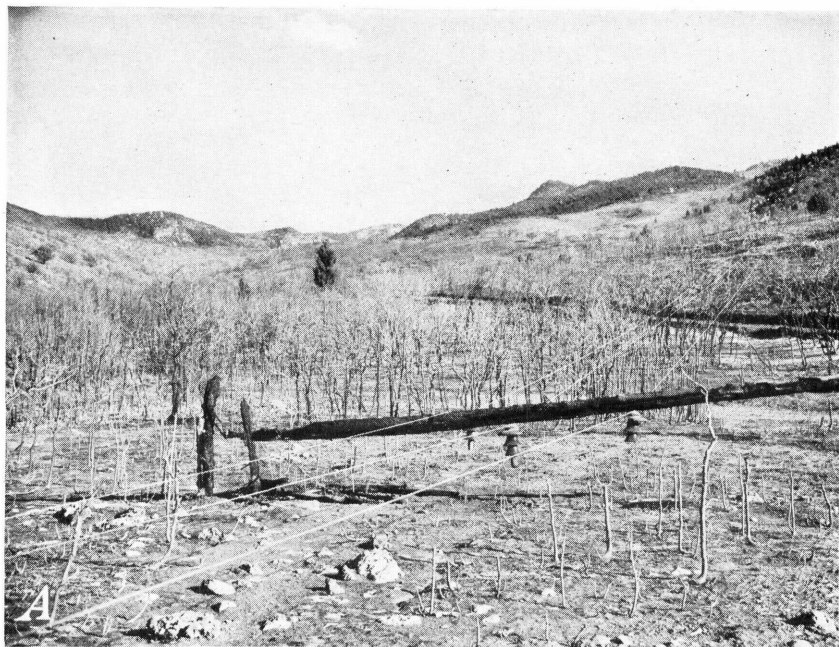
DISASTROUS RESULTS OFTEN FOLLOW HAPHAZARD BURNING

Haphazard burning differs little from accidental burning. It is undertaken (1) without sufficient concern for the fitness of the area to be burned; (2) without any notion of whether the burn is likely to succeed or to result in loss of forage; (3) without sufficient provision for the control of the fire; and (4) without a definite program of careful grazing management after burning to insure reestablishment and maintenance of the forage cover.

In contrast to the benefits from planned burning, accidental or haphazard burning nearly always produces damage or loss, often of disastrous proportions. Without adequate provisions for control, fires set to clear sagebrush from a small tract may sweep across wide areas and destroy feed, damage the range, and destroy property. The burned area may be so extensive that it is impossible to protect it properly from too early grazing or recurrent fires. Fires may run over the range of a nearby operator who cannot make the necessary adjustments to manage grazing properly after burning. It is burning of this haphazard or promiscuous nature that is beyond doubt chiefly responsible for the fact that so many burned-over sagebrush areas have been damaged rather than improved by fire.

The individual responsible for uncontrolled fires is often faced with heavy fines or costly civil suits. For example, in Utah during 1942, a fire set by a rancher to clear sagebrush from a 640-acre area escaped and swept over more than 7,000 acres of private, State, and Federal lands in one afternoon, destroying a power-transmission line, ruining a Government installation valued at \$24,000, killing over 100 deer in an experimental pasture, and causing much damage to private property (fig. 8). Individuals responsible were immediately faced with civil suits for \$4,000 damage to the power lines, and several thousand dollars additional damage to property and improvements on other lands. They were further subject to trial in criminal courts for failure to get a permit or observe Federal and State fire laws.

Soil is the basic resource upon which range productivity depends. If soil is damaged by fires or lost through subsequent erosion, range productivity is reduced for a long period. The haphazard burn that runs over steep slopes or range land poorly protected by understory vegetation exposes the soil to the full play of wind and water erosion. When the perennial understory before burning is sparse, the soil will be inadequately protected from erosion for a long period thereafter and serious losses are likely to occur. Soils that blow or wash easily, but have formerly been held in place by the vegetation, may begin to move when fire has removed the sagebrush or other plant

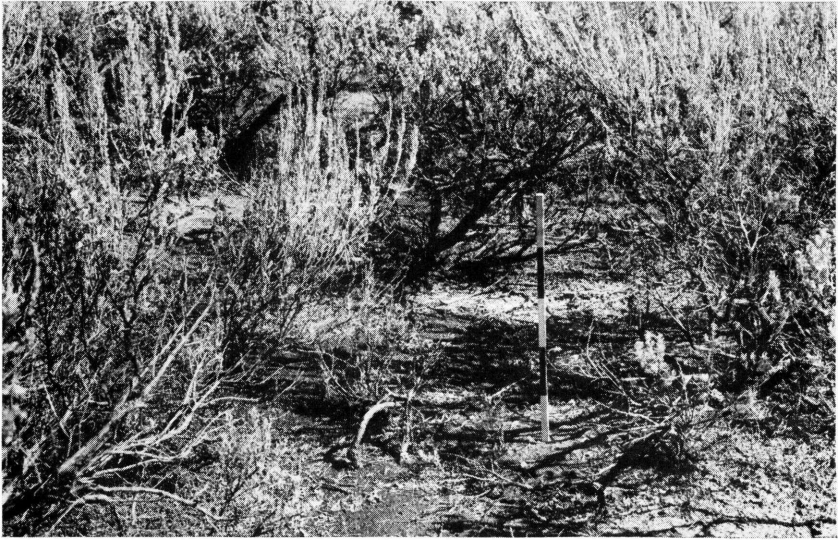


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FIGURE 8.—What happens when sagebrush fires are ineffectively controlled. A power line was badly damaged (A) and much personal property destroyed (B) by this "outlaw" burn, which also damaged the range and caused a very considerable loss of forage. The fire was set to clear sagebrush from a small area, but proper provisions for control were not made.

cover and may not be halted for several years after burning unless they are seeded. The frequent dense clouds of dust blown from newly burned areas are themselves evidence of wind erosion, as a result of which fertile top soil and range productivity are being lost. On steeper slopes rainfall runs rapidly from the exposed soil and carries with it the valuable surface layers. Recurrent burning intensifies these losses. Where the burn itself has not precipitated heavy soil losses, lack of provision for restricted grazing after the burn often works much havoc.

The value of forage cover is seriously reduced by the haphazard operation that disregards proper time for burning and fails to note whether the dominant perennial grasses and weeds can withstand a burn. Some forage species are destroyed by the heat of the fire itself, especially by spring and



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FIGURE 9.—Sagebrush range of this sort should not be burned unless preparation is made for reseeding to perennial grasses. The absence of such grasses beneath the dense sagebrush stand is typical of much of the sagebrush-grass type. The importance of reseeding is emphasized by the contrast between figures 7 and 10, showing after effects on the same burn.

midsummer fires. Some are killed by the consequent wind and water erosion which exposes the root crowns to severe freezing during the winter or to drying winds during the late summer and fall. But by far the greatest loss is from improper after-grazing that nearly always characterizes haphazard burning. This not only weakens further or kills many of the plants but also prevents the stand of grasses from taking advantage of the increased soil-water supplies and occupying the spaces left by removal of the sagebrush.

An even heavier stand of sagebrush returns rapidly where grasses and weeds do not offer stiff competition for soil moisture (figs. 9 and 10). Movement of livestock over the newly burned area brings the sagebrush seed in and scatters it. Soon there is a thick stand of young sagebrush plants which within 10 or 12 years will mature and once more cause a grazing problem. Burning is often resorted to again, but always with poorer prospects of improvement, unless the operation is carefully planned and carried out.

Cheatgrass brome³ replaces perennial grasses on many areas subjected to haphazard burning. Where some cheatgrass is present, burning the range as soon as the cheatgrass is dry will destroy or so damage the desirable perennial species as to open the way to increase of cheatgrass. Improper grazing of such range after burning will also aid the cheatgrass. This replacement increases the subsequent fire hazard, because of the greater inflammability of cheatgrass and the fact that it dries up a month earlier than do the perennial grasses. Recurrent burning from accidental or other fires, coupled with improper grazing, accelerates the replacement, until pure cheatgrass stands are brought about. With this change the grazing value of the forage cover is decreased, because of the short season during which



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FIGURE 10.—If perennial grasses and weeds provide no competition, the sagebrush will return almost immediately. Fire is not magic—it will not make grass. This view was taken at the same time as that in figure 7 and shows what is to be expected on such an area if it is not reseeded.

cheatgrass stays green and because of its wide fluctuation from year to year in volume of forage produced.

Once a dense stand of cheatgrass is brought about, range improvement by reseeding or grazing management is extremely difficult. Also the number and seriousness of accidental range fires is increased, since cheatgrass fires easily gain sufficient volume to travel over and damage other types of cover that normally are not very inflammable.

Cost of putting out uncontrolled or accidental fires and of protecting against them is excessive, yet they must be checked to protect adjacent range and property. Further, it is notable that in localities where haphazard burning is habitual, the public is generally indifferent to the dangers and damage of accidental fires. This indifference in turn produces carelessness in preventing fires along highways or near campgrounds and failure to check such accidental fires while they are still small, or to report them to the proper authorities. Haphazard burning itself and the increased number of accidental fires for which it is directly or indirectly responsible

³ Cheatgrass brome is commonly known locally as cheatgrass. In other localities it is known as bronco grass, downy brome, or downy chess.

make it necessary for fire protection agencies to maintain a larger organization for the control of fires and to spend much more money on suppression for a much longer period than might otherwise be necessary.

IMPROPER GRAZING THE WORST FEATURE

Improper grazing practice after burning is more frequently responsible for soil loss and damage to the plant cover than any other feature of haphazard burning. The character of the injury inflicted is clearly illustrated

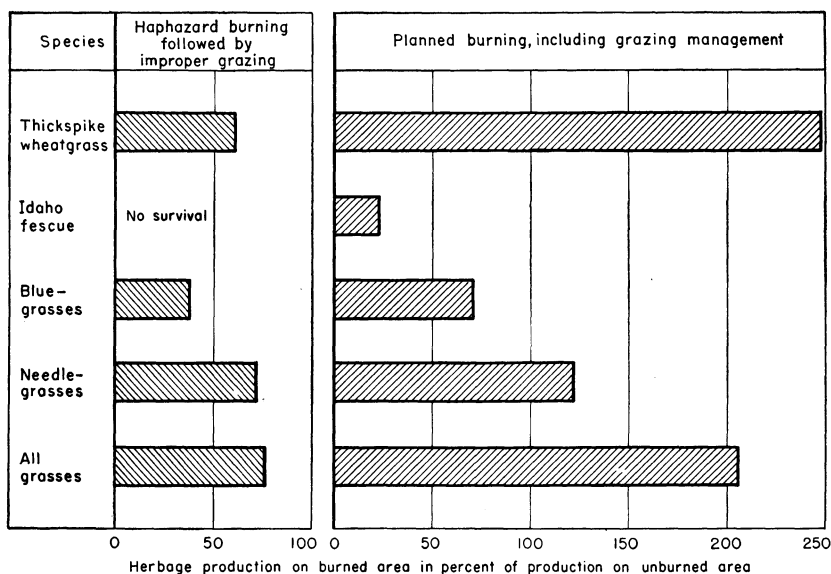


FIGURE 11.—The improper grazing of burned range destroys much of the desirable grasses unharmed by the fire, and further accentuates the damage to the species that are not fire-resistant.

by a comparison of the results on two areas burned in 1933—one the experimental area in Fremont County and the other a haphazardly burned range near Camas Creek in Clark County. Both were burned at about the same date, had an excellent understory of grasses and weeds before burning, and were of level or rolling topography. The essential difference between the two burns was in the manner of burning and the grazing management after burning. On the experimental area the Fremont County Woolgrowers' Association carefully controlled the fire and gave the range a full year's protection from grazing and trailing afterwards. The next year it was conservatively stocked and has so continued ever since. On the other hand, the Camas Creek tract was allowed to burn uncontrolled and without plan or preparation for proper grazing after burning. The uncontrolled fire swept on through and 2 miles past the intended limit. Sheep and cattle trailed across the range immediately after burning and it has been heavily grazed ever since.

Nine years after burning, the Fremont County area had 83 percent more grazing capacity than comparable unburned range, in contrast to a 4-percent increase at Camas Creek. These widely different results were due primarily to a 106-percent increase in perennial grasses on the Fremont County range, as compared with a decrease of 23 percent on the other (fig. 11). Further-

more, this decrease in grasses was accompanied by the immediate return of sagebrush in such abundance that, in 1942, 50 percent more sagebrush plants (fig. 12) occupied the burned lands than are found in comparable dense unburned stands. This plentiful stand of sagebrush plants, even though young, produced more herbage than did the unburned range (fig. 13). Grazing capacity here would have been even less had it not been for the large amount of relatively low-value forage furnished by the sagebrush. Thus, improper grazing after burning on the Camas Creek area seems accountable not only for the failure of the burned area to make substantial increase in grazing capacity but also for a decrease in the quality of the forage produced.

On the Fremont County area all perennial grasses but Idaho fescue and bluegrasses increased in production. In contrast, the only increase on the Camas Creek area was in Douglas sedge, which is included with "all

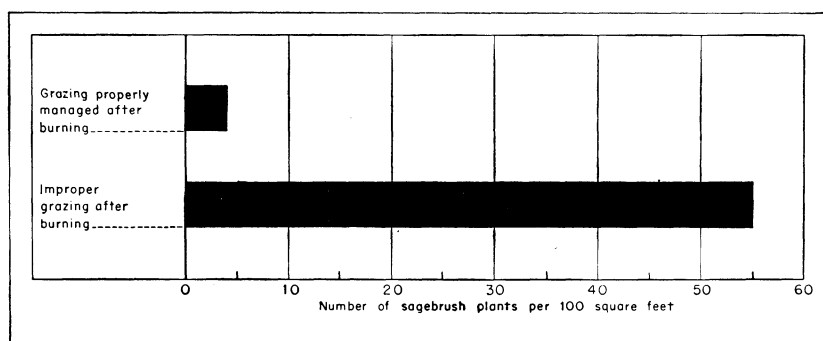


FIGURE 12.—Improper grazing management after burning is chiefly responsible for the very abundant return of sagebrush; the chart shows results tabulated 9 years after the burn. A dense stand of sagebrush is considered to be 35 plants per acre.

grasses" in figure 11. Even thickspike wheatgrass, a very fire-resistant species spreading rapidly by rootstocks, was reduced 39 percent by improper grazing, as compared with a 148-percent increase under good grazing management. Idaho fescue, normally not very fire-resistant, with a 23-percent survival under planned burning was completely killed out by haphazard burning. Bluegrasses, among the most palatable grasses on the spring-fall range of southeastern Idaho, were reduced 62 percent by the haphazard practice, but had a 71-percent survival following the planned burning.

Furthermore, soil losses and damage to soil fertility, only very slight under good grazing management, were serious at Camas Creek. These were due mainly to trailing and grazing the first year, which, together with severe grazing during later years, prevented any thickening of the herbaceous plant cover.

Thus, the problem of dense sagebrush is at best only temporarily relieved when burning is followed by improper grazing practices (fig. 14). Soil is less fertile, desirable perennial grasses and weeds are less abundant, and in some cases the less desirable annual grasses have increased. Within 10 to 15 years after burning, the sagebrush will once again form a dense stand and must again be eliminated. But the reduced understory of perennials and the less fertile soil will make any promise of range improvement much less certain than when the area was first burned.

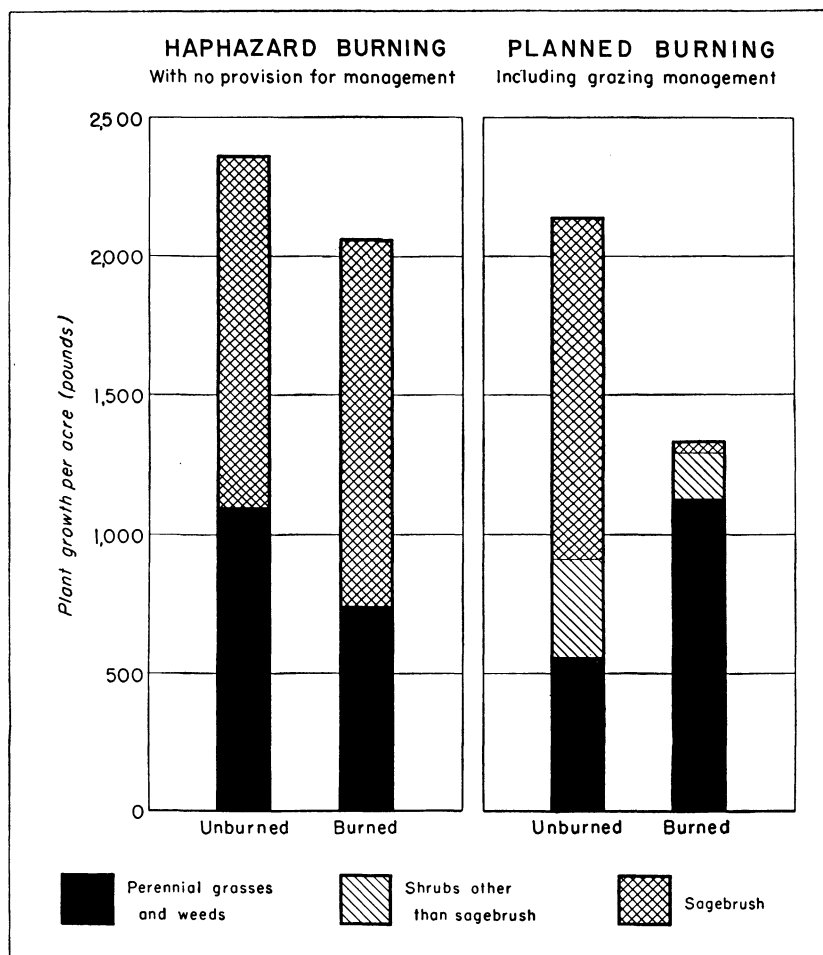


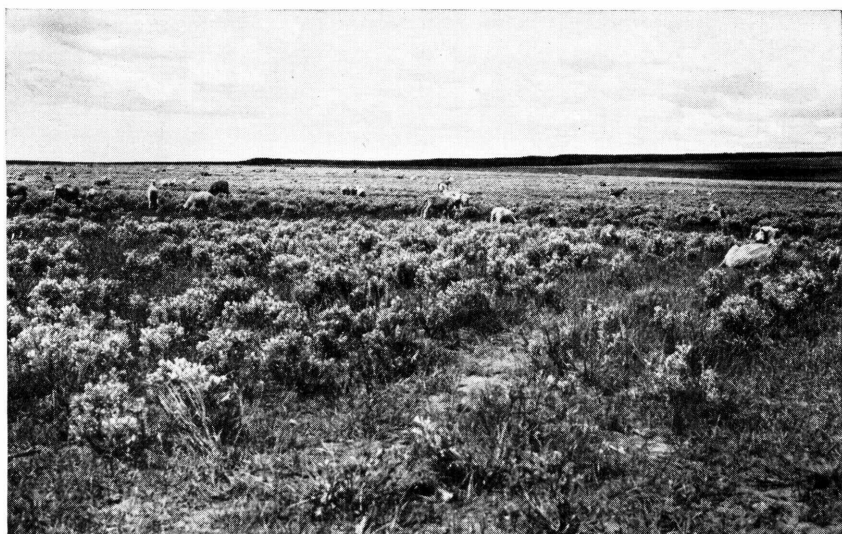
FIGURE 13.—Herbage production of different classes of vegetation under planned and haphazard burning and grazing. Proper grazing management after the burn prevents the return of the sagebrush and greatly promotes increase in the stand of perennial grasses and weeds. The fact that no provision for proper grazing is made in haphazard burning is one of the chief reasons why sagebrush so often returns in considerable quantities and perennial grasses and weeds are reduced.

ESSENTIAL CONSIDERATIONS IN PLANNED BURNING

The widely different results from proper and improper burning, and the care required to insure permanent good results, make effective planning absolutely necessary if burning is to produce the benefits desired.

Haphazard burning produces poor results because it is haphazard. Burning is like a fine tool or intricate machine; it must be used skillfully and in compliance with an intelligent plan, if good results are to be secured.

The considerations that distinguish planned from haphazard burning fall into four groups—where to burn, when to burn, how to burn, and how to manage the area after burning. The guide setting forth the various



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FIGURE 14.—Five years after a haphazard burn, characterized by no effort to adapt grazing practice to the needs of the range, the sagebrush has returned in considerable quantity and in another 8 or 10 years will form a stand so dense as to be very objectionable. Originally the stand of perennial grasses was heavier than that on the area shown in figure 1. The contrast between this view and that in figure 2 speaks for itself.

requirements for planned burning can be applied only after careful study of each individual area and the program for burning must then be formulated on the basis of the needs of that area.

WHERE TO BURN

Burn sagebrush range only where all of the following conditions prevail:

1. Where fires can be and will be controlled.
2. Where principal use of the area is for livestock grazing.
3. Where soils are fairly firm and slopes less than 30 percent.
4. Where big and threetip sagebrush are dense and form more than half the plant cover.
5. Where fire-resistant perennial grasses and weeds form more than 20 percent of the plant cover; or if they form less than 20 percent, reseeding to perennial grasses is practicable.
6. Where proper grazing practices can be and will be used after burning.

But:

1. NOT where the principal use of the area is for watershed, timber production, or important values other than grazing.
2. NOT where soils are highly susceptible to wind or water erosion.
3. NOT where important grasses, weeds, and browse are seriously damaged by fire.
4. NOT where more than half the understory is cheatgrass brome, unless the area can be protected from accidental fires.

Burn only where fires can be controlled.—The fire must be held to the area that it is intended to burn, if costly damage to other ranges and destruc-

tion of property are to be avoided. Only where fire has been so controlled can adequate provisions be made for protection from grazing after burning. Burning should never be attempted where it is economically impossible to construct satisfactory fire lines, or where the manpower necessary to assure control of the fire is not available. Cost of setting a fire may be negligible, but the cost of an uncontrolled fire may be exorbitant, as in the case of the Utah fire already mentioned.

Experience with the use of fire is a very important feature of control. Accordingly, it will usually be advisable the first year to burn an area small enough so that the difficulties of control can be thoroughly studied without endangering other land. Such a small preliminary burn will also show the possibilities in the use of fire under local conditions.

Burn only where principal use of the range is for livestock grazing.—In such situations, the increased grazing capacity and usability of the range as the result of careful burning will ordinarily outweigh the damage to lesser values. On the other hand, such gains on important watersheds may be more than offset by the loss of soil, damage to reservoirs, or flooding of croplands; on timber-producing lands, by the destruction of timber reproduction or mature trees; or on winter range for big game, by destruction of browse forage and resultant starvation of wildlife.

Burn only where soils are firm and slopes gentle.—Fairly firm soils on areas of level or rolling topography are not likely to be damaged by erosion following removal of the plant cover if a good perennial grass stand will clothe them the next spring. But where soils are likely to wash or blow, or where slopes are over 30 percent, danger from erosion is high and exposure of the soil may be disastrous. Burning seriously magnifies the danger from erosion by completely removing protection from the soil for the remainder of the summer, that fall, and the first part of the following spring. In many instances so much of the topsoil layer may wash or blow away that the roots of perennial grasses will be exposed and a good protective cover will be slow to become reestablished.

Burn only where sagebrush is dense.—Where sagebrush forms less than half the plant cover, it seldom interferes seriously with the handling of range livestock, and is even of value as sheep browse in the fall and for the protection it affords in cold periods in that season. Furthermore, where stands are not dense, the benefits to be expected from sagebrush removal are much less than in heavy stands. Removal makes available an amount of soil moisture roughly proportional to the density of the sagebrush. The increase in surviving species is limited by the amount of this moisture. Thus, in scattered stands of sagebrush, the degree of improvement to be expected from burning is not large enough to warrant the use of such a dangerous tool, its cost, or the year's loss in range use that is entailed.

Burn only where fire-resistant perennial grasses and weeds are abundant.—A stand of perennial grasses and weeds forming at least 20 percent of the plant cover is necessary if their spread after burning is to be rapid enough to prevent serious soil erosion and the early return of sagebrush. But it is essential that these grasses be largely of fire-resistant species. A heavy stand coming in after burning will stop soil loss by the first spring, whereas a light stand will permit erosion to continue for a year or two. Sagebrush seedlings, also, will have difficulty in surviving if all vacant spaces are filled and soil moisture is being used by perennial grasses and weeds. But to the degree that soil moisture is not utilized by the grasses and weeds, because of their sparseness, sagebrush seedlings will reinvade the unoccupied spaces and become firmly established. The longer excess soil mois-

ture remains available, the greater the chance for return of sagebrush. The larger the amount of moisture unused by the other vegetation, the greater the number of sagebrush plants likely to become established.

Sagebrush burning does not affect all plants the same way—some it injures seriously, some slightly, and some not at all. This varied effect is indicated in the following list of common plant species of the sagebrush-grass type of the upper Snake River plains, the condition of species at the end of the first growing season after burning being taken as the basis of classification. Names in italics indicate species that are important because of their abundance or because of their moderate or high palatability. Those undamaged species marked with an asterisk spread by rootstock or root shoots.

Species Severely Damaged

<i>Idaho fescue</i>	<i>Hoary phlox</i>
<i>Threadleaf sedge</i>	Saskatoon serviceberry
Low pussytoes	Big sagebrush
Littleleaf pussytoes	Threetip sagebrush
Uinta sandwort	Granite gilia
Englemann fleabane	Broom snakeweed
<i>Wyeth eriogonum</i>	<i>Antelope bitterbrush</i>
Mat eriogonum	

Species Slightly Damaged

<i>Bluebunch wheatgrass</i>	Timber poisonvetch
<i>Prairie Junegrass</i>	<i>Milkvetch</i>
<i>Indian ricegrass</i>	<i>Northwestern painted-cup</i>
<i>Sandberg bluegrass</i>	<i>Tapertip hawkbeard</i>
<i>Nevada bluegrass</i>	Sticky geranium
Cusick bluegrass	<i>Tailcup lupine</i>
<i>Subalpine needlegrass</i>	<i>Royal penstemon</i>
<i>Needleandthread</i>	Munro globemallow
Thurber needlegrass	

Species Undamaged

<i>Crested wheatgrass</i>	Velvet lupine
* <i>Thickspike wheatgrass</i>	* <i>Stansbury phlox</i>
* <i>Bluestem wheatgrass</i>	* <i>Flaxleaf plainsmustard</i>
Cheatgrass brome	* <i>Lambstongue groundsel</i>
* <i>Purple pinegrass</i>	Foothill deathcamas
* <i>Douglas sedge</i>	<i>Downy rabbitbrush</i>
* <i>Western yarrow</i>	Spineless gray horsebrush
Wild onion	* <i>Orange arnica</i>
<i>Arrowleaf balsamroot</i>	* <i>Common comandra</i>
* <i>Purpledaisy fleabane</i>	

In judging the adequacy of the perennial grass and weed understory it must be recognized that nonresistant plant species such as Idaho fescue, threadleaf sedge, the partially shrubby weeds, and bitterbrush may require years of careful grazing management to recover former abundance. Where these species form the major portion of the understory, burning may result in excessive soil erosion, early return of sagebrush after burning, and, in addition, the loss of these valuable species from the cover. These species should not be counted toward the 20 percent minimum limit, and other methods of removing sagebrush must be used on such lands. Large areas having dominant perennial grass and weed species not known to be resistant to fire should not be burned without preliminary tests on smaller areas to indicate whether the questionable species are fire-resistant.

Rapidity of increase by the lightly damaged or the uninjured species depends roughly upon whether they do or do not spread by rootstocks. Those that do not, even though undamaged, increase slowly after burning.

These include several of the more palatable species, such as bluegrasses, needlegrasses, junegrass, Indian ricegrass, arrowleaf balsamroot, and tailcup lupine. Despite a ready recovery from burning and rapid increase in vigor, any increase in number of plants must wait production of seed. This seldom occurs in any abundance until the second year after burning.

Plant species spreading by rootstocks or root shoots (marked with an asterisk in the list above) are least harmed and spread most rapidly after burning. Their underground stems and roots are unharmed and are ready for immediate increase. Such species as thickspike wheatgrass, Douglas sedge, western yarrow, Stansbury phlox, and purpledaisy fleabane will double in production within a 3- or 4-year period. They are, however, secondary in palatability. Their marked increase often hides the partial disappearance of more valuable species and may be largely responsible for an appearance of greater increase in grazing capacity than actually occurs. It is important that this be recognized in judging range improvement after burning.

Wherever less than one-tenth of the ground is covered by vegetation, less than 600 pounds of herbage (air-dry weight) per acre is produced, the annual precipitation is less than 9 inches, or there is moderate or greater likelihood of soil washing or blowing, it is imperative that fire-resistant perennial grasses and weeds make up more than 20 percent of the plant cover; else, after burning, the plant cover may not be thick enough to prevent serious soil losses. Where the erosion hazard is moderate or greater, immediate revegetation is essential to prevent exposure of the soil for longer than the fall, winter, and spring immediately after burning. If vegetation is light on such areas, sagebrush should not be burned, even though provision can be made for reseeding.

Burn areas deficient in fire-resistant perennials only when reseeding is practicable. Information on where reseeding is likely to succeed, what species to use, and how to plant can be secured from several State and Federal publications⁴ or from local men who are experienced in grazing management and reseeding work. Where reseeding is not likely to succeed or where it is not practicable, areas having less than the minimum limit of perennial grasses and weeds should not be burned.

Where cheatgrass brome is dominant in the understory, full protection against recurrent fires must be assured.—Cheatgrass is an annual and a very prolific seeder. Its seed is seldom damaged by sagebrush fires. The year following fire, cheatgrass is likely to take over all the available space before the perennial grasses and weeds recover sufficiently from burning to occupy it. Once established, cheatgrass will retard increase in perennial grasses and weeds. Although the perennials, if not further retarded, will eventually overcome the competition, the handicap of injury by midsummer fires or overgrazing will so hold them back that cheatgrass will further replace them. Thus, if dense sagebrush is burned from areas that have heavy stands of cheatgrass, it is essential to provide special protection against accidental fires in addition to the good grazing management given any planned burn.

Burn sagebrush only where grazing management is planned and provided for.—Where planned grazing practices are not practical, or are not employed, burning the range can result only in short-lived increase in grazing capacity and will almost certainly be expensive in terms of lost range productivity.

⁴ HALL, A. C., and PEARSE, C. K. HOW TO RESEED SOUTHERN IDAHO RANGE LANDS. Research Paper No. 2. Intermountain Forest and Range Expt. Sta. 22 pp. 1943. [Processed.]

SHORT, L. R. RESEEDING TO INCREASE THE YIELD OF MONTANA RANGE LANDS. U. S. Dept. Agr. Farmer's Bul. 1924, 26 pp., illus. 1934.

STEWART, G., WALKER, R. H., and PRICE, R. RESEEDING RANGE LANDS OF THE INTERMOUNTAIN REGION. U. S. Dept. Agr. Farmer's Bul. 1823, 25 pp., illus. 1939.

WHEN TO BURN

Burn Sagebrush Range:

1. In the late summer or early fall.
2. Not earlier than 10 days after perennial grass seed is ripe and scattered and leaves are nearly dry.

But:

1. NOT in the spring or midsummer.
2. NOT as soon as cheatgrass is dry.
3. NOT in a drought year.

Wait till 10 days after seed of perennial grasses is ripe and scattered.—Other indicators of this date of readiness are that Sandberg bluegrass has been completely dry for nearly a month, spineless gray horsebrush seed is ripe, downy rabbitbrush has just finished blooming, and big and threetip sagebrush are just about to begin blooming.

The need for burning at this time, and not before, is illustrated by figure 15, showing the relative effects of burning at different dates on the production and vigor of bluebunch wheatgrass the following year.

Do not burn in the spring.—Burning in the spring (May 10 to May 30) has serious effects on the perennial grasses and weeds that are just then making active growth or beginning to flower. Large portions of the grass clumps and weeds are killed, production is greatly reduced, and the way is paved for the early return of sagebrush and other undesirable plants. When the range is burned in spring, plants produce in the following year less than one-

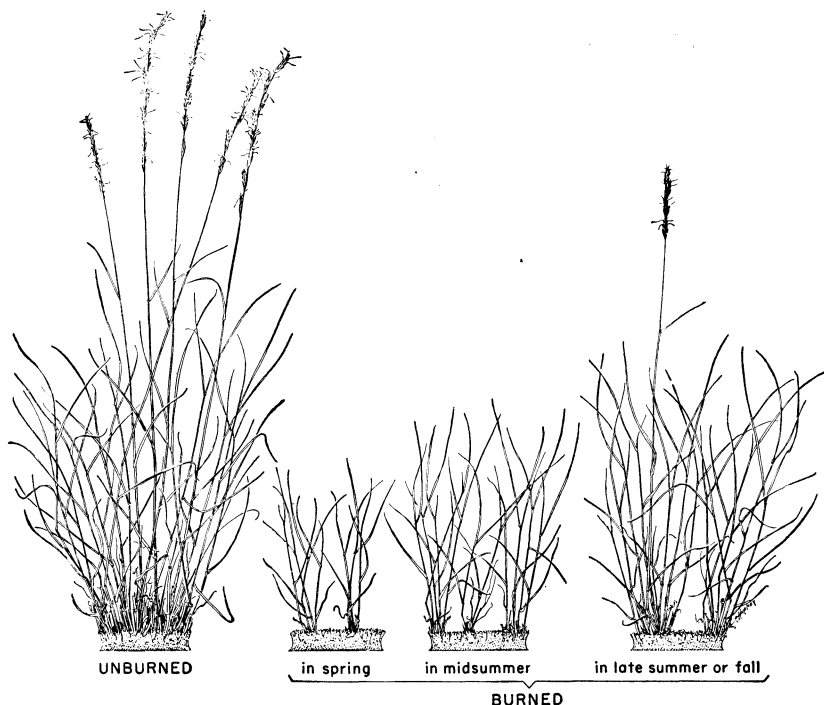


FIGURE 15.—Effect on clumps of bluebunch wheatgrass of burning the previous year—in the spring, in midsummer, and in the late summer or early fall—as compared with no burning.

tenth as much as unburned plants, leaves are reduced in length, and grass clumps split up badly.

Midsummer drying of cheatgrass is not a signal for burning.—On ranges with an abundance of cheatgrass the likelihood of too-early burning is great, since this common annual grass dries 4 to 6 weeks before associated perennial grasses and weeds (fig. 16). Fires will burn readily 2 or 3 weeks before seed of the perennial species ripens and herbage begins to dry. Perennial grasses burned in the period from shortly before their seed is ripe until the seed is disseminating will be seriously injured and will produce in the following year less than one-third the forage produced on unburned plants. Clumps will be badly split up, as after spring burning, and leaves will be reduced in length. Furthermore, midsummer burning increases the chances for serious soil loss by wind and water erosion. The period of soil exposure

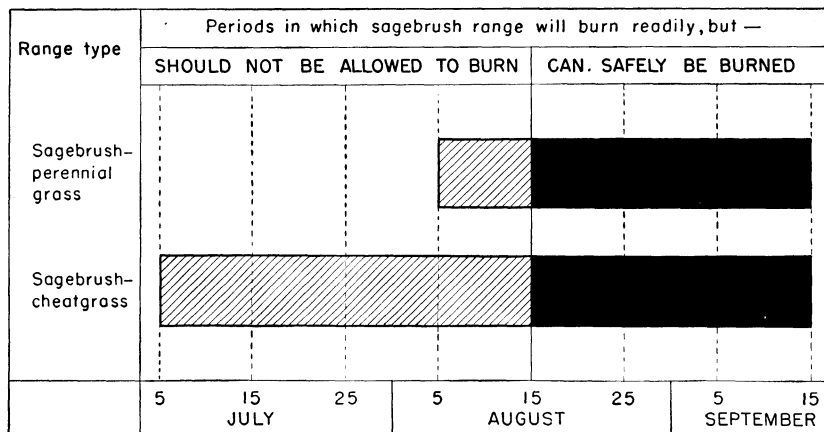


FIGURE 16.—Summer and fall periods during which sagebrush range on the upper Snake River plains will burn, when it should be burned, and when it should not be burned. Sagebrush range should never be burned in the dry period before the spring and summer rains.

to possible torrential summer storms and high winds is lengthened, since these are most likely to occur during July and the first part of August.

Burn in late summer or early fall.—If the burn comes after seed is disseminated and when leaves are drying rapidly, reduction in vigor of grasses will be held to 30 to 40 percent the following year; some splitting up of clumps will occur, leaves will be somewhat shorter than on unburned plants, and fewer flower stalks will be produced. While this amount of damage may appear great, under proper grazing practice the valuable perennials will recover and by the second year may be producing even more than before.

Time burning by plant growth.—It is important that proper dates for burning be determined from the plant growth each year, rather than by any set calendar date. On most of the upper Snake River plains bluebunch wheatgrass seed is not usually disseminated nor do the leaves begin to dry rapidly until after August 10. But elevation or other causes may advance or retard the maturity of palatable and otherwise desirable plants, and the date of burning must be adjusted accordingly. At the slightly higher elevations on the upper Snake River plains adjacent to national forests there is frequently only a short period during the latter part of August

when sagebrush will burn satisfactorily and when it should be burned.

Burning should not be done in a drought year.—All range forage is needed in a drought year because of lowered production. Plants already weakened by the impact of the drought are likely to be killed out partially or wholly by added injury from burning. Furthermore, fire is difficult to control in a drought year, when all vegetation is tinder-dry, winds are of high velocity, temperatures high, and humidities low. These characteristics are all conducive to extremely hot fires.

HOW TO BURN

Burn only after:

1. All local and Federal fire laws have been carefully studied and a burning permit has been obtained.
2. A program for burning has been prepared.
3. Adequate fire lines have been constructed around the area.

Then:

1. Select carefully the day for burning so that there is certainty of a good burn but no chance that the fire will get out of control.
2. Have plenty of well-trained men, equipment, and supplies on hand before the fire is started.
3. Start the fire late in the day.

But:

1. DO NOT burn without a permit.
2. DO NOT burn where adequate control of the fire cannot be assured.
3. DO NOT burn without adequate control lines, men, and equipment.
4. DO NOT burn when high winds are blowing or impending.
5. DO NOT leave fires burning—be sure every fire is put OUT.

Be properly informed.—Get from the local fire warden, State forester, or nearest employee of the Forest Service or Grazing Service full information on local and Federal fire laws. Federal statutes state that it is a criminal offense for anyone to set on fire or cause to be set on fire any timber, underbrush, or grass or other inflammable material upon the public domain or other lands owned and leased by the United States, or to set fires near such lands, without the permission of the United States. In addition nearly all Western States have fire laws governing the use of fire within the State, requiring permits to burn during certain seasons of the year, and setting up requirements for the "safe" use of fire. Get a permit to burn from the local fire warden and, if county, State, or Federal land is involved, additional permission from the agency under whose jurisdiction the land falls. Lack of knowledge is no excuse for failure to comply with the law and will not save the violator from heavy fines, nor prevent civil suits being brought against him for damages his fires may cause to the property of others.

Prepare a program for burning, in which all phases of fire control, burning, and grazing management have been considered. It is essential to determine before any further steps are taken precisely the equipment needed for fire-line construction, the men for fire control, the seed and equipment for reseeding if that is necessary, and the additional range or feed supplies to permit protection of the burned areas for a year. Then make sure that all these essentials are available.

The burning program must be adjusted to the availability of additional range feed to care for the livestock during the period of nongrazing, since this

may limit the area of range that can be burned in any one year. A program of rotation burning may be advantageous. Such a program, illustrated by figure 17, provides for the burning each year of not more than one-quarter of the land planned for improvement. Rotation burning minimizes the area of supplementary range to be leased and the quantity of feed to be purchased. Rotation burning will not be advantageous if immediate im-

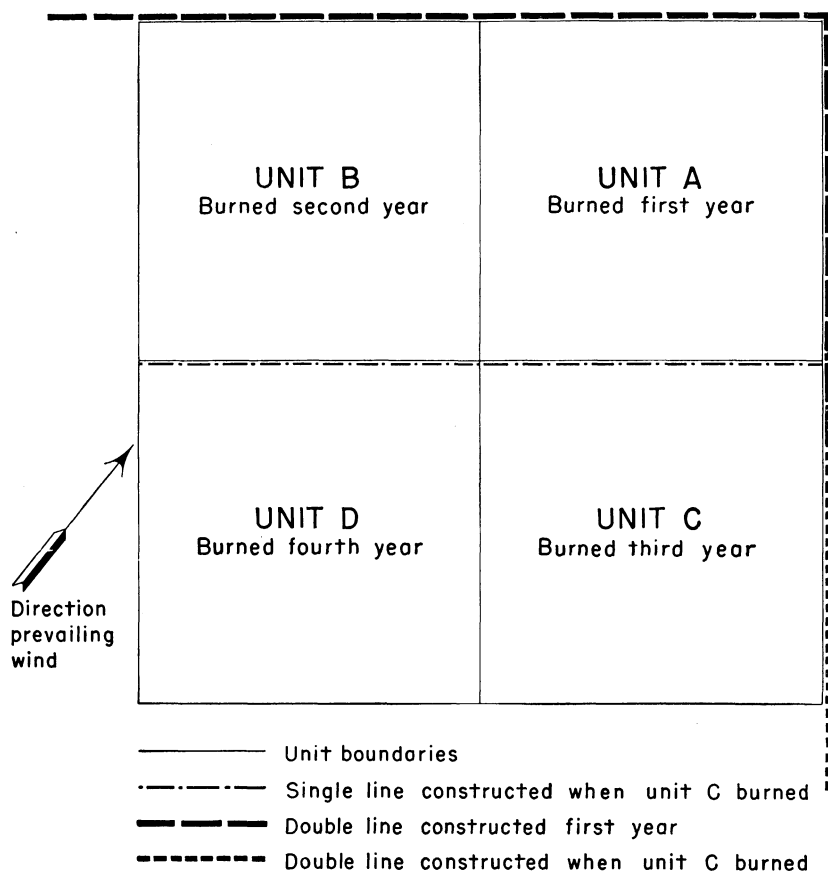


FIGURE 17.—Diagram of a 4-year rotation burning schedule where the understory is predominately perennial grasses and weeds, showing location of fire lines. Where cheatgrass forms a fair proportion of the understory, a single line will be needed on the two windward sides of the area to be burned each year.

provement of the entire area is essential or if enough additional forage to permit a year's protection, or fences for the needed distribution of cattle, cannot be obtained. Burning the entire area at one time is more economical in actual burning costs and lessens the liability of livestock trailing over the edges of newly burned areas and other chances for the return of sagebrush.

Construct adequate fire lines around the area.—Burning can be done successfully only when there is relatively high fire danger, hence the fire that escapes from control is almost sure to be serious and dangerous. Careful

preparations must be made to confine fire within fire lines, and these must be adequate to stop the fire under the most hazardous conditions.

On ordinary sagebrush-perennial grass range, a double fire line 50 to 100 feet wide, extending along the leeward side (the side toward which the wind commonly blows in the afternoon) and at least a quarter-mile past the side limits of the burn is sufficient. On cheatgrass and other range of unusual inflammability, however, single cleared lines 8 feet or so wide are required on all other sides. Cheatgrass will burn briskly in all directions, even against the wind. Similar precautions may be needed where the sagebrush is extremely tall (3 to 6 feet), where control is likely to be hazardous because of a heavy cover of litter on the ground, or where wind direction is notably changeable.

With rotation burning, location of fire lines takes advantage of the fact that sagebrush fires rarely travel over 1-year-old burns and are easily arrested with the aid of a single line on 2-year-old burns. The rotation burning illustrated in figure 17 is planned for an area subject to a southwest wind. Burning begins in 1943 with the northeast quarter. As a safety factor in extremely hazardous seasons when there has been a heavy plant growth, a single furrow or lightly graded line through the 1-year-old burn may be desirable. In addition, where cheatgrass is heavy in one or several of the unburned units, single lines will be needed on the windward side. Some maintenance may be required on cleared lines constructed the previous year, but in the interest of economy as much line as possible should be constructed when equipment is on the ground. They may often be used then and afterwards as roads for handling livestock and hauling water and supplies.

The mechanical work on the double fire line consists of clearing two parallel strips (the one nearer the fire about 12 feet wide, the other 7 to 8 feet) separated by a 2- to 4-foot uncleared strip (fig. 18). The purpose of the uncleared center strip is to stop the drift of hot ashes and litter from the fire. The strip offers so little fuel that any fire that starts there is not likely to jump the adjacent cleared line and, if it does, can be easily whipped out. Single fire lines are cleared mechanically to a width of 8 feet. Cleared strips of either the double or single lines should be scraped free of all plant cover, sagebrush, grass or litter, to the mineral soil.

Mechanical work on the cleared lines can be carried out in the summer, well ahead of the season for burning. Caterpillar tractor and bulldozer, or caterpillar tractor and power grader, have been used in constructing fire lines at the U. S. Sheep Experiment Station. The "cat"-grader combination was the more satisfactory. A road patrol performs well where the soil is fairly free of rocks. Well-traveled roads, if they are entirely free of vegetation, may be utilized for fire lines if they are backed up with a narrow uncleared strip and a cleared line.

Widening of the cleared double lines to the 50 to 100 feet needed for adequate protection against escape of fires may be done as soon as the perennial grasses are dry enough. Backfiring should be used, firing to windward progressively back from the mechanically cleared line when the wind is blowing toward the line. In this way, the hazard of escape of the backfire is low, and fire-control lines will be well established by the time the proper date for burning arrives. In areas of heavy brush and grass, a 4- to 6-foot strip should be burned out before setting fires back to any greater depth. Under ordinary fire hazard, the single line on the windward side or in front of 2-year-old burns will not need to be widened.

Several men should be used in backfiring—at least three to prevent escape of the fire for each man setting fires. Fires jumping to the uncleared

center strip should be put out immediately; soil thrown forcefully at the fire, by use of a long-handled round-point shovel, is very effective.

Backfires should not be permitted to burn unattended during the day or at night, because they tend to break up the cover into large islands of unburned sagebrush separated by narrow burned streaks. Where this has happened, burning the area is costly, and it is difficult to secure a clean burn. Furthermore, fires left burning at nightfall may be swept outside fire lines by the night wind that is often from a direction opposite to that during the afternoon. Accordingly, backfires should be put out as soon as lines have been widened sufficiently, but in any case before the area is left each day.

After fire lines have been constructed, it is advisable to have them inspected by someone experienced enough to detect weak spots where fires



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FIGURE 18.—Double type of fire line mechanically cleared on the leeward side of an area from which sagebrush is to be burned. A little later in the season the wide strip to the left will be extended by backfiring to a depth of 50 to 100 feet.

might sweep across. When fire lines are adequate and perennial grasses have reached the proper stage of development, preparations for burning are complete.

Select a hot, dry day with a steady, moderate wind.—Fairly fast crown fires are needed in sagebrush burning, lest the fire split and go around thin stands of sagebrush on shallow rocky areas or rock outcrops and leave the leeward sagebrush unburned. To produce the type of fire needed, temperatures must be high, humidities low, and wind of a moderate velocity and from a prevailing direction. Cloudy days, when changeable wind direction may cause patchy burns or sweep the fire out of control, and days when the wind is blowing so hard as to cause undue danger of the fire getting out of hand, must be avoided. The United States Weather Bureau should be called upon for a forecast of the possibility of unusual wind or other weather conditions that might affect burning.

Have plenty of well-trained men, equipment, and supplies on hand.—Weed or pricklypear burners for setting fire to the area, ordinary round-point shovels,

water and water containers, and, if available, backpack fire pumps, as well as a first-aid kit, must be ready when the proper day for burning comes. Sufficient men should be on hand (15 or 20 men for a 1,000 or 2,000-acre burn) to patrol the entire leeward side of the burn area and put out any fires that are working to the windward from where the fire is set. These men should be trained while the cleared fire lines are being backfired, so that they will know what to expect from sagebrush fires and how to put out escape fires.

Start the fire late enough in the day so that if it does escape, little time will remain before temperatures drop, humidities rise, the wind goes down or reverses direction, and fires burn less briskly. The shorter the time in which the fire can burn rapidly, if it does escape, the less will be the damage to adjacent property before it is brought under control. On the upper Snake River plains fires set at 3:30 to 4 p. m., Mountain War Time, will have time to burn rapidly over 1,000 to 2,000 acres of range before burning conditions change.

The procedure in setting the fire varies with wind condition and direction. One system for use on a square tract similar to that shown in figure 17, to be burned under a southwest wind, is to burn the north half first and then the south half. In setting the fire, it is advisable to begin at the northwest corner, proceed south half the way to the south border, and then turn due east and set fire along the entire south side of the north half. Then, after the fire has burned up to the north fire line, the southern half of the area can be burned, proceeding as with the north half. It is important to set fires so that a solid wall of fire will sweep across the area. Setting a number of individual fires tends to produce an undesirably patchy burn.

The man setting the fires should move along rapidly, setting a continuous line of fire. Three men should accompany him to put out any fires working to the windward, outside of the area that it is intended to burn. The remainder of the crew should be placed along the fire line to patrol the uncleared center strip and the adjacent land outside control lines. Escape fires will seldom result from flaming pieces of brush or sparks flying through the air and over the fire line, but are more likely to arise on the uncleared strip from glowing embers blown along the ground, and may jump to the outside if not promptly extinguished. It is advisable to split the crew up into groups of three men, each group to patrol a sector of the line near the point at which the fire will strike. At the moment the fire hits the backfire area, those on patrol duty will need to watch carefully for fires in the center uncleared strip and adjacent outside unburned area. As soon as the fire within the burned area has died down at one point, the patrol at that sector can move on to another sector, leaving one of their group to guard the line.

Local fire wardens or employees of the Forest Service or Grazing Service are well trained in matters pertaining to the control of fires. Their advice in preparing fire lines, in burning the area, and in control of the fire will be very helpful in preventing escape of fire used in burning.

Adequate precautions must be taken to insure safety of the men employed on sagebrush burning. Sagebrush fires travel rapidly in the dense cover and there is constant danger of personal injury if the men are not well organized and instructed. Crews should be given well-trained, responsible leaders who will know what to do in case of emergency. No individual should be permitted inside the control lines on the area being burned while burning is in progress.

Put out all fire before leaving the area, to insure the safety of adjacent property. As long as a fire is burning, there is always a chance that it can get outside control lines.

Cooperation in burning is desirable.—With present shortages of labor and the demand for hay and pasturage, necessary personnel may be difficult to get, as may be additional pasturage or hay to use during the time that burned areas are being given the needed protection. Large livestock operators, livestock associations, and Federal, State, or local agencies may have sufficient personnel, equipment, and range land to use planned burning satisfactorily. But the small operator may have to cooperate with other small operators in using planned burning.

MANAGEMENT AFTER BURNING

Management essential to favor the perennial grasses and weeds demands:

1. Protection of burned areas from trailing by livestock during the first fall at least.

2. Protection of burned areas from grazing for 1 full year.

3. Light grazing the second year, and thereafter no heavier than the range can support permanently.

4. The same grazing management for burned and reseeded areas as for areas not in need of reseeding.

5. For areas with more than half the understory in cheatgrass, special protection against recurrent accidental fires.

6. For accidentally burned areas, at least as good management after burning as that demanded for the best results from planned burning.

Grazing practice following burning is the most important single factor determining whether burning turns out well or badly. Even accidental burns may produce good results on areas where conditions are otherwise favorable to burning if grazing is properly managed afterward. On the other hand, all the care taken to avoid burning at the wrong place and season and to control the fire may go for naught if improper grazing practices follow burning.

Protect perennial grasses and weeds.—They are the most valuable plants for spring-fall grazing use and the ones that good grazing management of these ranges aims to maintain or increase. They are more palatable and furnish a more consistent supply of forage than annuals—forage that is especially valuable during both the spring and fall seasons. They are much less inflammable than cheatgrass. Furthermore, they provide the best type of cover for protecting the soil against wind and water erosion. They will generally increase relative to annuals if protected against trampling, if not grazed before they become well established, and if grazed moderately thereafter. If not so protected, they cannot well compete with the less nourishing and less palatable annuals.

Protect burned areas from trailing.—Trailing livestock across the burned area the first fall stirs up the unprotected dry soil and speeds wind or water erosion. The trailing livestock bring in sagebrush seed, primarily in their fleece or hair, and scatter it over the burned areas; it is seldom scattered any great distance by the wind or stored in the soil. The young sagebrush seedlings that come up early the first spring will be firmly established before the perennial grasses and weeds recover sufficiently to prevent it. Thus, trailing may alone be responsible for the reinvasion of sagebrush. If livestock must be moved across the burned area the first spring, this can be

done with least damage to the plants and soil by moving the animals slowly and keeping them well spread out.

Do not graze for 1 full year after burning.—The amount of forage obtainable the first year is small and can be grazed only at the cost of serious damage to soil and desirable perennial plants. Any attempt to graze the scattered growth of perennial species and cheatgrass that occasionally comes in on the newly burned area after early fall rains will have the same effects as trailing—loss of soil and return of sagebrush, in addition to marked injury to the perennials that made regrowth.

As has been pointed out, the appearance of an abundance of green growth in the spring is deceptive. The reduced vigor of nearly all species is lost sight of because all the grasses and weeds on the area are exposed to full view at one time. Actually, the desirable plants have been weakened, some of them seriously (fig. 15). Grazing at this time is certain to utilize the more palatable species most heavily and further lower them in vigor or kill them out. In this weakened condition many of the perennial grasses and weeds are prevented from increasing in size or abundance, and the plant cover is kept so open that sagebrush can successfully return. Furthermore, grazing the open plant cover will stir up the inadequately protected soil and speed up wind and water erosion.

Graze lightly the second year and moderately thereafter.—It has been seen that at the end of the first year most of the plants are still suffering somewhat from the effects of burning. But in the second fall after burning the perennial species have matured and light grazing will not damage them. It may, in fact, help to plant any seed produced by perennial species. Anything more than light use must be avoided, however, especially if the grass stand is light.

Grazing should continue to be light through the second spring, even though there is often a marked increase in forage. This is normally a period of heavy seed production by all perennials, the first since burning, and offers opportunity for the more desirable and palatable species to increase in numbers.

Rate of grazing on the burned area during the second year and thereafter should be based on the abundance of perennial grasses and weeds and recovery made by them. In general, the same number of animals carried under conservative grazing the fall and spring before the burn can be accommodated in these seasons in the second year after burning. This rule will hold only if the perennial grasses and weeds have made satisfactory progress since burning and have suffered no drought. Beginning the third year after burning, the number of animals can be increased if the improvement in the perennial grass and weed cover justify an increase. Thereafter grazing should be adjusted to what the range can support on a permanent basis.

Light grazing is especially important where cheatgrass forms a preponderance of the cover. Any effort to utilize cheatgrass fully will result in overgrazing the perennial grasses and weeds, which are at all times much more palatable than cheatgrass.

Other practices that promote good grazing management.—These include good distribution of livestock, proper season of use, open herding, proper location of salt grounds, and rotation grazing management. These and all other practices that further good range use and thus assure maintenance of benefits derived from burning should be employed to help in maintaining increased grazing capacity and usability of the range.

Adapt grazing to rotation burning.—In rotation burning, each newly burned portion must have protection against grazing for 1 year. In an operation in which the range was fully stocked before burning, this necessitates leasing or purchasing additional range, providing other feed equivalent to the forage burned each year for the period of the rotation, or reducing the number of livestock. Only where there was actual understocking before burning should the unburned portions be made to carry some or all of the livestock from the freshly burned portion. In that case, however, the increases in stocking must be gaged strictly by the grazing capacity of the unburned range.

A sample grazing schedule for an area similar to that shown in figure 17 is presented in table 1 for the years 1943–47. In this case, it is assumed that additional pasturage or feed is available for the first part of the spring season and the end of the fall season, so that, when burning starts and for 1 year after it is completed, the full number of animals graze the area for only three-quarters of the customary spring and fall seasons. In the spring, grazing use is so rotated that each unit is grazed during the same period of the spring season only once every 4 years. Such rotation is unnecessary in the fall, inasmuch as the plants are then mature. The unit to be burned each year should be grazed first in the spring of that year, so as to take advantage of the forage produced and permit growth after grazing to accumulate as much herbaceous fuel as possible.

TABLE 1.—*Spring and fall grazing schedule for rotation¹ burning, allowing the year of protection needed for each unit after burning*

Year and season	Unit A—burned 1943	Unit B—burned 1944	Unit C—burned 1945	Unit D—burned 1946
1943:				
Spring	Period 1.	Period 2.	Period 3.	Period 4.
Fall		$\frac{3}{4}$ season.	$\frac{3}{4}$ season.	$\frac{3}{4}$ season.
1944:				
Spring		Period 2.	Period 3.	Period 4.
Fall	$\frac{3}{4}$ season.		$\frac{3}{4}$ season.	$\frac{3}{4}$ season.
1945:				
Spring	Period 4.		Period 2.	Period 3.
Fall	$\frac{3}{4}$ season.	$\frac{3}{4}$ season.		$\frac{3}{4}$ season.
1946:				
Spring	Period 3.	Period 4.		Period 2.
Fall	$\frac{3}{4}$ season.	$\frac{3}{4}$ season.	$\frac{3}{4}$ season.	
1947:				
Spring	Period 2.	Period 3.	Period 4.	
Fall	Full season.	Full season.	Full season.	Full season.

¹ Units A, B, C, and D are equal in grazing capacity; as indicated in the headings, one is burned each year from 1943 to 1946. Spring grazing season is divided into four 15-day periods—April 24–May 9, May 9–May 24, May 24–June 8, and June 8–June 23; fall grazing runs from October 1 to November 15 during the burning operation, but thereafter for the full season, to December 1. In the spring of 1943 and the fall of 1947, and of course, thereafter, the entire range is grazed for the full season; at all other times on the schedule the area is grazed for three-quarters of the season starting 15 days later in the spring and ending 15 days earlier in the fall.

By the fall of 1946 the entire area has been burned over and in the fall of 1947 grazing is resumed for the full season. No subsequent burning will be necessary. If the progress made by perennial species justifies it, the period of grazing on Unit A may be lengthened beginning with the fall season of 1945, and that of Unit B beginning with the fall of 1946. If this can safely be done it may relieve somewhat the need for pasturage or feed in 1945–47.

Rotation burning and subsequent rotation grazing can be used more readily on sheep ranges, because sheep movements from unit to unit can be easily controlled by the herder. With cattle this system is somewhat more difficult, requiring fences to prevent cattle from congregating on the newly burned area and the older burns, and to facilitate rotation between the

units. Electric fences, where practicable, would provide a low-cost method for managing the distribution of cattle.

It is particularly hazardous to graze a new stand of grass seedlings.—Young and weak-rooted grass seedlings are easily killed out by trampling or pulled out by grazing animals. They are, therefore, critically in need of complete protection from grazing or trailing the first year after burning and seeding, to permit them to become firmly established. Good stands of grass have been obtained on reseeded areas that were grazed lightly or conservatively during the first growing season, but much more rapid and vigorous growth will be made if the areas are protected. In the second fall any attempt to graze the area fully will cause far more damage than the negligible quantity of forage furnished by the newly seeded stand will offset. Light grazing during the second year and the application of other principles of good grazing management thereafter are necessary to increase and maintain the stand of reseeded perennials.

Cheatgrass areas must have special protection against recurrent accidental fires.—The removal of sagebrush from dense cheatgrass areas and the temporary increase of cheatgrass greatly increases the inflammability of the cover for a large part of the summer. Special precautions are needed to prevent accidental midsummer fires and subsequent loss of forage, injury to the perennials, and further increase of cheatgrass. The danger can be minimized by the construction of single cleared fire lines along railroads, highways, or well-traveled roads, where accidental fires are most likely to start. Spread of fire can be minimized by clearing lines to divide the area into blocks; and if these are cleared with a grader, removing the cheatgrass and the seed on the ground surface, they may be successfully reseeded to crested wheatgrass or other perennial grasses or to yellow sweetclover. The perennials, in the absence of competition by cheatgrass, are likely soon to form permanent belts of relatively noninflammable plant cover, which should give permanent protection and at the same time increase grazing capacity.

Give accidental burns protection from grazing.—The above guides for grazing management after burning are for areas where all requirements regarding where and when to burn have been given thorough consideration before burning. Each year there are, however, thousands of acres of sagebrush range accidentally burned. On these, no grazing or trailing the first spring, light grazing the second year, and the application of other principles of good grazing management should be of great value in avoiding further loss of the forage that survives. In every instance the practices outlined as a part of planned burning will apply. If the accidental fire happened to come in later summer or early fall and was confined to a level or rolling area that had a good understory of perennial grasses, the application of proper grazing practices will bring back the range at least to its former grazing capacity and is likely to produce the same good results obtained by planned burning.

Additional care is often needed where accidental fires occurred early in the summer, where they covered cheatgrass areas, steep slopes, readily erodible soils, areas with too sparse stands of grass, or with Idaho fescue or other nonresistant species as a major portion of the understory. To prevent serious damage in such cases, special treatment is essential, such as longer periods of protection from grazing or light or deferred grazing.

COSTS OF RANGE IMPROVEMENT BY PLANNED BURNING

Total costs of range improvement by planned burning of sagebrush range are made up of the costs of constructing the fire lines, of actually burning the area (including the wages of crews used for patrolling line), of grazing protection where additional range must be leased or additional hay purchased, and of reseeding where that is necessary following sagebrush removal. Costs vary widely, depending upon the size and shape of area to be burned, the presence of roads or streams which can be taken advantage of as firebreaks, and the length of new fire line needed.

The major cost is that of adequate fire lines. The total cost of double lines is approximately \$40 per mile, \$25 for clearing it with heavy equipment, and \$15 for widening through backfiring. Single cleared lines cost from \$15 to \$20 per mile. Rocky soils, irregular topography, extremely large and dense sagebrush will increase the costs of line construction.

The total cost of burning computed on the basis of a rectangular 1,000-acre area, $1\frac{1}{2}$ miles by 1 mile in size, with an adequate perennial grass and weed understory, is \$0.19 per acre (table 2), supposing that two sides must be protected by double fire lines, as in figure 17. If tracts of 4 sections (2,560 acres), forming a square area 2 miles on a side, are burned at one time, costs are reduced to \$0.13 per acre. Cost of burning increases directly with the length of fire line required. Only 5 miles of line are required for the 2,560-acre area as compared with 3 miles of line needed for the 1,000-acre area.

To these costs must be added at least \$0.10 per acre for loss in grazing privileges; and where reseeding is necessary following burning, from \$1.20 to \$2 per acre.

TABLE 2.—Costs of range improvement by planned burning of sagebrush-grass range calculated on the basis of a rectangular 1,000-acre tract,¹ exclusive of reseeding and grazing protection

Item	Cost per day	Total cost
Fire lines, mechanical work:		
Rental of caterpillar tractor (16 hours)	\$17. 20	\$34. 40
Rental of grader (16 hours)	5. 00	10. 00
Caterpillar and grader operators (2 men, 16 hours each)	16. 00	32. 00
Total		76. 40
Backfiring double line (10 man-days)	4. 50	45. 00
Burning area (10 man-days)	4. 50	45. 00
Miscellaneous costs—burners, kerosene, transportation		25. 00
Total cost of burning area		191. 40
Cost per acre 19

¹ Approximately $1\frac{1}{2}$ by 1 mile. Double lines required on one side and one end.

On cheatgrass areas, costs of control are increased by the cost of the single line needed on the windward sides of the area.

On cattle ranges, the cost of temporary fences needed to control the cattle should be added to the total cost.

LIST OF ACCEPTED COMMON NAMES AND SCIENTIFIC NAMES OF SPECIES MENTIONED

Grasses and Grasslike Plants

Bluegrass, big	<i>Poa ampla</i>
Bluegrass, Cusick	<i>P. cusickii</i>
Bluegrass, Nevada	<i>P. nevadensis</i>
Bluegrass, Sandberg	<i>P. secunda</i>
Brome, cheatgrass ("cheatgrass," "bronco-grass," "junegrass")	<i>Bromus tectorum</i>
Fescue, Idaho	<i>Festuca idahoensis</i>
Junegrass, prairie	<i>Koeleria cristata</i>
Needleandthread	<i>Stipa comata</i>
Needlegrass, subalpine	<i>S. columbiana</i>
Needlegrass, Thurber	<i>S. thurberiana</i>
Pinegrass, purple	<i>Calamagrostis purpurascens</i>
Ricegrass, Indian	<i>Oryzopsis hymenoides</i>
Sedge, Douglas	<i>Carex douglasii</i>
Sedge, threadleaf	<i>C. filifolia</i>
Wheatgrass, bearded bluebunch	<i>Agropyron spicatum</i>
Wheatgrass, bluestem	<i>A. smithii</i>
Wheatgrass, crested	<i>A. cristatum</i>
Wheatgrass, thickspike	<i>A. dactylochium</i>

Weeds

Arnica, orange	<i>Arnica fulgens</i>
Astragalus	<i>Astragalus salinus</i> ; <i>A. stenophyllus</i>
Balsamroot, arrowleaf	<i>Balsamorhiza sagittata</i>
Comandra, western	<i>Comandra pallida</i>
Deathcamas, foothill	<i>Zigadenus paniculatus</i>
Eriogonum, mat	<i>Eriogonum caespitosum</i>
Eriogonum, Wyeth	<i>E. heracleoides</i>
Fleabane, Engelmann	<i>Erigeron engelmanni</i>
Fleabane, purpledaisy	<i>E. corymbosus</i>
Geranium, sticky	<i>Geranium viscosissimum</i>
Globemallow, Munro	<i>Sphaeralcea munroana</i>
Groundsel, lambstongue	<i>Senecio integerrimus</i> (<i>lugens</i>)
Hawksbeard, tapertip	<i>Crepis acuminata</i>
Lupine, tailcup	<i>Lupinus caudatus</i>
Lupine, velvet	<i>L. leucophyllus</i>
Onion	<i>Allium</i> spp.
Paintedcup, northwestern ("Indian paint-brush")	<i>Castilleja angustifolia</i>
Plainsmustard, flaxleaf	<i>Schoenocrambe linifolia</i>
Penstemon, royal	<i>Penstemon speciosus</i>
Phlox, hoary	<i>Phlox canescens</i>
Phlox, Stansbury	<i>P. stansburyi</i>
Sandwort, Uinta	<i>Arenaria uintabensis</i>
Yarrow, western	<i>Achillea lanulosa</i>

Shrubs

Bitterbrush, antelope	<i>Purshia tridentata</i>
Chokecherry, black common	<i>Prunus melanocarpa</i>
Gilia, granite	<i>Gilia pungens</i>
Horsebrush, spineless gray	<i>Tetradymia canescens inermis</i>
Rabbitbrush, downy	<i>Chrysothamnus viscidiflorus puberulus</i> (<i>C. puberulus</i>)
Sagebrush, big	<i>Artemisia tridentata</i>
Sagebrush, threetip	<i>A. tripartita</i>
Serviceberry, Saskatoon	<i>Amelanchier alnifolia</i>
Snakeweed, broom	<i>Gutierrezia sarothrae</i>
Snowberry, mountain	<i>Symphoricarpos oreophilus</i>

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